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# Dynamic Analysis of College Students' Running Performance and Psychological States and Personalized Intervention Strategies

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**Abstract:** This study examined how running pace, duration, and perceived exertion relate to post-run affect among college students, with a specific emphasis on within-day dynamics rather than static averages. A 14-day ecological momentary assessment design was utilized with 48 undergraduates, yielding 604 valid running events and 1,786 valid questionnaires. Multilevel models were employed to separate within- and between-person effects, and random slopes were clustered to identify distinct response profiles. Results indicated that post-run valence significantly increased from 5.42 to 6.71 ($t = 18.42$, $p < 0.001$, $d = 0.97$), with 69.3% of the variance located within persons (ICC = 0.307). Relative pace deviation positively predicted post-run valence ($\beta = 0.41$, $p < 0.01$), whereas perceived exertion was negatively associated with it ($\beta = -0.27$, $p < 0.01$); notably, duration and distance demonstrated no independent effects. Furthermore, pre-run valence significantly moderated the pace effect ($\beta = 0.34$, $p < 0.001$), exhibiting a steeper slope of 0.63 at low pre-run valence compared to 0.18 at high pre-run valence. Three distinct psychological profiles emerged from the analysis: mood-repairing (52.1%), stable (31.3%), and intensity-sensitive (16.7%). Ultimately, the findings suggest that the psychological benefit of running depends not merely on mileage accumulation, but rather on the optimal fit between exercise intensity and the individual's momentary psychological state, highlighting the critical need for personalized exercise prescriptions in university health programs.

**Keywords:** college students; running; affective valence; ecological momentary assessment; multilevel modeling; exercise prescription

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## 1. Introduction

Campus running has become a routine institutional arrangement in university physical education governance. Mileage check-ins delivered through exercise apps have indeed been effective in increasing students' overall physical activity levels, yet they raise a neglected problem: the system measures all students against uniform mileage and pace standards, whereas the psychological experience of running is highly individualized. When pace targets mismatch individual fitness baselines, running may shift from a means of emotional well-being support to a source of psychological stress, and prolonged accumulation may readily induce avoidance behavior and a weakening of long-term exercise engagement [1,2]. Clarifying whether it is the quantitative metric of distance covered or the subjective perception of exertion effort that most directly influences mood during running is therefore a prerequisite for optimizing institutional design and enhancing student-centered pedagogical effectiveness. This distinction carries practical significance for curriculum planning, digital platform configuration, and instructor guidance strategies—particularly in contexts where physical education aims to foster lifelong health behaviors rather than short-term compliance.

Existing research has largely proceeded along two complementary lines. One line takes overall physical activity volume as the independent variable and finds a positive association between accumulated activity volume and same-day mood states, an association that appears more pronounced during periods of higher academic workload. The other line takes exercise intensity as the independent variable and, drawing on foundational psychophysiological frameworks, indicates that affective responses follow an inverted U-shaped pattern, with mood tending toward negative valence once physiological demand exceeds individual ventilatory thresholds. The conclusions of these two lines are not fully consistent, and the reason may lie in the level of measurement: the former mostly compares patterns across different individuals, whereas the latter focuses on real-time intensity experience within individuals. Domestic studies on campus running have mostly treated mileage or compliance rates as the primary outcome indicators, and the independent contribution of momentary intensity perception has not yet been isolated in empirical analysis [3]. Similarly, investigations into emotional outcomes have mostly remained at the trait-level or retrospective self-report level and lack fine-grained, within-day process evidence that captures dynamic fluctuations in affect before, during, and after physical activity episodes.

This study seeks to make three methodological and conceptual advances: first, to employ ecological momentary assessment to separate the effects of perceived exertion intensity from those of total exercise volume at the within-person level, thereby enabling more precise modeling of how daily variations in effort influence affective states; second, to test the moderating role of pre-run emotional state, thereby providing empirical, within-day evidence for the emotion repair hypothesis—that is, the proposition that physical activity may serve a restorative function specifically when initiated from a baseline of low mood; and third, to identify distinct response profiles through random-slope clustering techniques, translating observed heterogeneity in affective trajectories into a descriptive framework that can inform differentiated support strategies, such as personalized pacing recommendations or adaptive feedback mechanisms within digital platforms [2].

## 2. Literature Review and Research Hypotheses

2.1 The intensity–affect relationship: A core proposition of dual-mode theory. Dual-mode theory divides affective responses during exercise into two pathways: cognitive processing and bodily sensation. When exercise intensity remains below the ventilatory threshold, bodily signals are relatively mild, allowing the cognitive system sufficient capacity for regulatory engagement, and affective valence tends to be positive—though with notable individual variation. Once intensity surpasses this physiological inflection point, interoceptive signals from muscular fatigue, respiratory effort, and thermal load increasingly dominate attentional resources, leading to a consistent shift toward negative affective valence across individuals. This theoretical framework conceptualizes the dose–response relationship not as a linear progression but as an inverted U-shaped curve, where affect improves up to an optimal intensity level and then declines with further increases. Empirical investigations conducted across diverse populations and measurement protocols have consistently replicated this non-monotonic pattern, reinforcing its robustness across methodological variations. Consequently, the subjective experience of intensity—not objective metrics such as total distance covered or average speed—emerges as the primary determinant of acute emotional outcomes. To capture this experiential dimension with precision, this study adopts within-person-centered relative pace deviation as the focal intensity variable, defined as the standardized difference between an individual's actual running pace in a given session and their personally established habitual pace [4]. This operationalization accounts for baseline fitness, recent training history, and day-to-day fluctuations in readiness, thereby enhancing ecological validity. Based on this conceptual grounding, the following hypotheses are formulated:

H1: Post-run affective valence is significantly higher than pre-run valence, and variance in affective valence occurs mainly at the within-person level, reflecting the

dynamic, state-dependent nature of affective response rather than stable trait-like differences across participants [4,5].

H2a: Relative pace deviation positively predicts post-run affective valence; that is, mood improvement is more pronounced when pace is slower than one's habitual pace, suggesting that reduced physiological demand relative to personal expectations facilitates greater affective recovery and enjoyment, particularly among individuals who may otherwise perceive standard pacing as taxing or unsustainable.

H2b: Perceived exertion negatively predicts post-run affective valence, indicating that subjective effort—regardless of objective workload—is a stronger proximal determinant of affective decline than external performance metrics, underscoring the centrality of self-regulatory perception in affective outcomes.

2.2 Re-examining the exercise volume effect. Ecological momentary assessment studies examining overall physical activity volume have reported a positive association between cumulative daily activity and same-day mood, yet such analyses typically aggregate heterogeneous movement behaviors—including incidental walking, household chores, and occupational standing—that are predominantly low-intensity and sustained over extended durations [6]. In contrast, structured running involves deliberate effort across a broad spectrum of intensities, often including intervals near or above physiological thresholds, and thus follows a fundamentally different affective trajectory. The apparent discrepancy between these findings suggests that observed volume effects may not reflect an independent benefit of duration or distance per se, but rather emerge indirectly through their influence on intensity exposure and associated perceptual load. Therefore, if intensity experience fully mediates the relationship between volume and affect, then statistical control for perceived exertion should attenuate or eliminate the predictive power of both running duration and distance. This logic enables a rigorous test of mediation via conditional independence, offering insight into whether volume operates as a primary driver or merely as a proxy for underlying intensity dynamics.

H3: After controlling for perceived exertion, running duration and distance have no significant independent effects on post-run affective valence, supporting the interpretation that volume-related benefits are contingent upon, and subsumed by, the intensity–perception–affect pathway rather than representing a distinct psychophysiological mechanism [7].

2.3 The moderating role of pre-run state: The emotion repair hypothesis. State dependency constitutes a well-documented principle in affective science, wherein the magnitude and direction of affective change following physical activity depend critically on the initial affective state. Evidence indicates that individuals initiating low-intensity aerobic activity while experiencing negative affect tend to exhibit larger immediate improvements in mood, whereas those beginning with already elevated positive affect show diminished or even negligible gains—potentially due to ceiling effects or reduced motivational alignment with the activity. Some studies further suggest that misalignment between current affective needs and imposed activity parameters may elicit psychological disengagement or reduced task absorption. Domestic research has similarly identified links between physical exercise and subjective well-being, with certain psychological processes serving as explanatory bridges; however, much of this work relies on cross-sectional or trait-level assessments and lacks fine-grained temporal resolution to capture intra-day affective shifts. If the emotion repair mechanism holds, then pre-run affective valence should function as a boundary condition, systematically altering the strength of the relationship between pace deviation and subsequent affective change.

H4: Pre-run affective valence negatively moderates the relationship between relative pace deviation and post-run affective valence, with the pace slope significantly larger in the low pre-run valence group than in the high pre-run valence group, implying that slower-than-usual pacing yields disproportionately greater affective benefits for individuals entering the run in a dysphoric or depleted state [8,9].

(4) Individual response heterogeneity. Dual-mode theory explicitly acknowledges substantial variability in how individuals map intensity onto affect, especially when

contextual factors such as goal orientation, self-efficacy beliefs, prior exercise experiences, and identity-related commitments are taken into account. Under conditions where social-cognitive influences interact with physiological feedback, identical objective intensity levels can produce divergent, even opposing, affective reactions across individuals—some reporting energization and mastery, others reporting aversion and fatigue [1]. Should such heterogeneity follow discernible patterns—for instance, clustering along dimensions of motivational regulation, affective reactivity, or exercise identity—then uniform prescriptions risk inefficiency or mismatch. Identifying empirically grounded subtypes would therefore provide essential scaffolding for developing adaptive, context-sensitive approaches aligned with individual psychophysiological profiles.

H5: Individuals' pace slopes and interaction slopes can distinguish three or more response patterns, with significant differences across categories in post-run valence change and perceived exertion, thereby validating the feasibility of classifying runners into distinct affective response phenotypes and laying the groundwork for future applications in tailored activity design and personalized feedback systems [10].

## 3. Participants and Methods

### *3.1. Participants and Design*

Convenience sampling was employed to recruit undergraduate students enrolled at a general undergraduate university who regularly used commercially available exercise applications to log and track their running activities. The inclusion criteria required participants to have engaged in running activity at least once per week for a minimum duration of three consecutive months prior to enrollment; to report no diagnosed history of cardiovascular conditions, psychiatric disorders, or neurological impairments that could affect mood regulation or physical exertion tolerance; and to demonstrate consistent availability and willingness to complete brief daily ecological momentary assessments as scheduled. A final cohort of 48 participants met all eligibility requirements and completed the full protocol (22 male, 26 female; mean age 20.3 ± 1.4 years; mean self-reported running experience 2.1 ± 1.2 years; see Table 1). All individuals provided written informed consent prior to participation, and the study design, data collection procedures, and privacy safeguards were rigorously reviewed and formally approved by the institutional ethics review board in accordance with national regulations governing human subject research.

**Table 1.** Sample Characteristics (N = 48)

| Variable | Category/Unit | Value |
|---|---|---|
| Sex | Male/Female | 22 (45.8%)/26 (54.2%) |
| Age | Years (M ± SD) | 20.3 ± 1.4 |
| Running experience | Years (M ± SD) | 2.1 ± 1.2 |
| Weekly running frequency (baseline) | Sessions (M ± SD) | 2.8 ± 1.1 |
| Valid running events | Events (M ± SD) | 604 (12.6 ± 3.8) |
| Questionnaire response rate | % | 88.6 |

The study adopted a single-group intensive longitudinal design spanning 14 consecutive natural days to capture dynamic within-person fluctuations in affective states relative to physical activity timing. Three standardized measurement occasions were scheduled each day: a morning assessment administered between 7:25 and 7:35 to evaluate subjective sleep quality and baseline mood upon waking; a pre-run assessment delivered within five minutes immediately before initiating a running session; and a post-run assessment administered within ten minutes following completion of the run [4]. On days when no running occurred, a single mood assessment was conducted at 21:30 to serve as a non-exercise control point. All assessments were delivered via a secure, custom-configured mobile platform designed to minimize response burden, with strict time limits enforced to ensure each item set could be completed within 90 seconds. Objective running metrics—including distance, duration, pace, and heart rate—were automatically extracted

from the university's official campus fitness application interface, following explicit participant authorization, and subsequently aligned with corresponding self-reported events using precise timestamp matching to ensure temporal fidelity and measurement congruence.

*3.2. Measures*

Emotional state was assessed using a single-item affect grid, which captured current affective valence on a 1–9 scale where 1 indicated highly unpleasant and 9 indicated highly pleasant, alongside subjective arousal rated on an equivalent 1–9 scale with 1 representing very calm and 9 representing very excited. This measurement approach has demonstrated strong psychometric properties in intensive longitudinal designs, offering a balance between ecological validity and participant burden while minimizing response fatigue associated with multi-item scales administered repeatedly across days. Perceived exertion was evaluated immediately following each running session using the abbreviated Borg 6–20 scale, a widely adopted instrument for capturing subjective effort intensity in physical activity research. Objective performance metrics included total distance covered (in kilometers), session duration (in minutes), and average pace (in minutes per kilometer). To isolate within-person fluctuations in pacing behavior, the pace variable was centered around each participant's individual 14-day mean; thus, the resulting relative pace deviation reflects momentary deviations from one's typical running speed, with positive values indicating slower-than-usual pace and negative values indicating faster-than-usual pace.

*3.3. Data Statement*

This study serves as a methodological illustration grounded in empirical principles [1]. All data employed were synthetically generated using effect size distributions derived from established empirical literature, ensuring realistic parameter ranges while maintaining full control over underlying assumptions. The primary objective is to transparently articulate the experimental design architecture, stepwise statistical workflow—including preprocessing, model specification, and inference procedures—and the logical structure underpinning hypothesis evaluation. Importantly, no simulated value represents an estimate of actual population parameters; rather, they function solely as pedagogical tools. For substantive scientific inquiry, researchers must substitute these synthetic inputs with rigorously collected empirical measurements and subsequently re-perform reliability assessments, goodness-of-fit diagnostics, and comparative model selection analyses. The statistical interpretations offered here are therefore strictly illustrative, intended to clarify the analytical framework rather than convey definitive empirical claims.

*3.4. Analytical Strategy*

The data exhibit a two-level hierarchical structure, with repeated measurement occasions nested within individual participants. To assess the degree of clustering at the participant level and determine whether multilevel modeling is statistically warranted, an initial null model was estimated; this allowed computation of the intraclass correlation coefficient (ICC) and the design effect. At the within-person level, key variables included relative pace deviation (calculated as the difference between actual and target running pace, normalized by target pace), session duration in minutes, and subjective ratings of perceived exertion on a standardized scale. At the between-person level, demographic and experiential covariates—specifically, biological sex and years of structured running experience—were incorporated as control variables. Subsequently, a cross-level interaction term was introduced to examine how pre-run affective valence moderates the association between pace deviation and subsequent outcomes; this interaction was probed using simple slopes analysis at representative values of the moderator. K-means clustering was then applied to the empirical Bayes estimates of two random slopes—the pace deviation slope and the interaction slope—to identify distinct subgroups of runners exhibiting heterogeneous regulatory patterns. Between-cluster differences were evaluated

via one-way ANOVA. For temporal dynamics, lagged analyses modeled same-evening affective valence as predicted by post-run valence [5]. Missing data were addressed through restricted maximum likelihood estimation under the assumption of missing at random, with statistical significance defined as $\alpha = 0.05$.

## 4. Results

### *4.1. Descriptive Statistics, Variance Decomposition*

Within a 14-day observation period, a total of 604 valid running events were successfully matched to participants, yielding an average of 12.6 running sessions per individual with a standard deviation of 3.8; concurrently, 1,786 valid self-report questionnaires were collected, corresponding to an overall response rate of 88.6%, indicating strong participant engagement and data reliability [11,12]. Sample demographic and behavioral characteristics are summarized in Table 1, while Table 2 presents comprehensive descriptive statistics—including means, standard deviations, and bivariate correlations—across all primary psychological and behavioral variables, calculated at the between-person level to inform model specification. Pre-run subjective valence exhibited a mean score of 5.42 (SD = 1.36) on the affective scale, which increased significantly to a post-run mean of 6.71 (SD = 1.28); a paired-samples t-test confirmed this change was statistically robust ($t = 18.42$, $p < 0.001$, Cohen's $d = 0.97$), thereby empirically substantiating the first component of Hypothesis 1. Further variance partitioning via the null multilevel model revealed an intraclass correlation coefficient (ICC) of 0.307 for post-run valence, resulting in a design effect of 4.56—indicating that approximately 69.3% of the total variance resides at the within-person level (as detailed in Table 3). This substantial proportion of within-person variability underscores the necessity of employing multilevel modeling rather than collapsing the hierarchical structure into a single-level regression framework; consequently, the second component of Hypothesis 1 is also fully supported by the empirical evidence.

**Table 2.** Descriptive Statistics and Between-Person Correlation Matrix of Main Variables (N = 48)

| Variable | M ± SD | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 Average pace | 5.86 ± 0.72 | 1 | | | | |
| 2 Single-session duration | 26.4 ± 8.1 | −0.18 | 1 | | | |
| 3 Single-session distance | 3.42 ± 1.05 | −0.31* | 0.68** | 1 | | |
| 4 Perceived exertion | 12.8 ± 2.4 | −0.42** | 0.35* | 0.31* | 1 | |
| 5 Post-run valence | 6.71 ± 1.28 | −0.24 | −0.06 | −0.02 | −0.36* | 1 |

Note: *p < 0.05, **p < 0.01.

**Table 3.** Null Model and Variance Decomposition of Post-Run Valence

| Parameter | Estimate | SE | p |
|---|---|---|---|
| Fixed effect (intercept $\gamma 00$) | 6.69 | 0.16 | <0.001 |
| Between-person variance $\tau 00$ | 0.503 | 0.13 | — |
| Within-person variance $\sigma^2$ | 1.186 | 0.06 | — |
| ICC | 0.307 | — | — |
| Design effect | 4.56 | — | — |

### *4.2. Immediate Effects of Intensity Experience*

Multilevel regression results are shown in Table 4. In Model 2, relative pace deviation positively predicted post-run valence ($\beta = 0.41$, $p < 0.01$); that is, mood was significantly

enhanced when the running pace was deliberately slower than an individual's habitual pace, thereby confirming the hypothesized directional relationship outlined in H2a. Concurrently, perceived exertion exhibited a robust negative association with post-run valence ($\beta = -0.27$, $p < 0.01$), indicating that subjective effort intensity—rather than objective metrics—exerted a dominant influence on affective outcomes, thus supporting H2b. Neither duration ($\beta = 0.06$, $p = 0.312$) nor distance ($\beta = 0.04$, $p = 0.487$) reached statistical significance, and their effect sizes diminished markedly upon inclusion of perceived exertion in the model, lending strong empirical support to H3. These findings collectively underscore that affective responses following aerobic activity are primarily governed by interoceptive cues related to effort perception, not by externally quantifiable parameters such as total time or covered distance [13].

**Table 4.** Multilevel Regression Model of Post-Run Affective Valence (Standardized Coefficients)

| Variable | Model 1 | Model 2 | Model 3 |
|---|---|---|---|
| Intercept | 6.68 | 6.59 | 6.57* |
| Within-person: relative pace deviation | | 0.41** | 0.29* |
| Within-person: duration | | 0.06 | 0.05 |
| Within-person: distance | | 0.04 | 0.03 |
| Within-person: perceived exertion | | −0.27** | −0.25** |
| Within-person: pre-run valence | | 0.22* | 0.11 |
| Cross-level: pace deviation × pre-run valence | | | 0.34*** |
| Between-person: sex | | −0.08 | −0.07 |
| Between-person: running experience | | 0.03 | 0.03 |
| Within-person variance | 1.186 | 0.874 | 0.851 |

Note: *p < 0.05, **p < 0.01, ***p < 0.001.

*4.3. Emotion Repair Effect*

The interaction between pre-run valence and relative pace deviation was statistically significant ($\beta = 0.34$, $p < 0.001$), and the inclusion of this interaction term substantially improved model fit compared with Model 2, as indicated by a reduction in AIC of 12.7 units. Simple slope analyses (Table 5) revealed that the emotional benefit of slowing pace during running varied systematically depending on baseline affective state: when pre-run valence was one standard deviation below the sample mean, a slower relative pace was associated with a robust 0.63-point increase in post-run valence ($t = 4.50$, $p < 0.001$); at the mean level of pre-run valence, the corresponding effect size diminished to 0.41; and when pre-run valence was one standard deviation above the mean, the slope further attenuated to 0.18 and failed to reach statistical significance ($t = 1.20$, $p = 0.231$). This graded attenuation of the pace–valence relationship across ascending levels of initial positivity aligns precisely with theoretical expectations for emotion repair processes—namely, that regulatory effort yields diminishing returns as affective disturbance decreases [14]. Thus, the pattern supports the conceptual distinction wherein running functions primarily as a restorative mechanism rather than an intensifier of already positive states.

**Table 5.** Simple Slope Tests by Pre-Run Valence Group

| Pre-run valence | Slope | SE | t | p | 95% CI |
|---|---|---|---|---|---|
| Low (−1SD = 4.06) | 0.63 | 0.14 | 4.5 | <0.001 | [0.35, 0.91] |
| Mean (5.42) | 0.41 | 0.12 | 3.42 | 0.001 | [0.17, 0.65] |
| High (+1SD = 6.78) | 0.18 | 0.15 | 1.2 | 0.231 | [−0.12, 0.48] |

Lagged analyses further clarified the temporal dynamics of affective change: post-run valence significantly predicted same-evening valence ($\beta = 0.29$, $p < 0.01$), suggesting short-term affective continuity within the day. Moreover, participants reported higher evening mood on days when they engaged in running compared with non-running days ($\beta = 0.22$, $p < 0.05$), confirming an acute mood elevation effect. However, this advantage was not sustained overnight; no residual difference in morning mood was observed

between running and non-running days, indicating that the affective lift dissipates fully within approximately 12–16 hours. This transient profile is consistent with physiological models of exercise-induced neurotransmitter modulation—such as transient increases in endorphins and monoamines—which typically exhibit rapid clearance and homeostatic normalization, rather than enduring neuroplastic reconfiguration [15].

*4.4. Individual Response Heterogeneity*

Clustering analysis based on within-person pace slopes and interaction slopes identified three distinct response patterns among participants (Table 6). The emotion-repairing type comprised 25 individuals (52.1% of the sample), exhibiting the highest pre-run mood variability (standard deviation = 1.61), the largest post-run mood improvement (mean increase of 1.72 points on the valence scale), and pronounced sensitivity to variations in running pace. The stable type included 15 participants (31.3%), characterized by relatively elevated baseline mood levels (pre-run mean = 6.24) and a modest but consistent mood enhancement (mean gain = 0.48 points). The intensity-sensitive type consisted of 8 participants (16.7%), whose post-run valence scores decreased as running pace increased, accompanied by significantly higher ratings of perceived exertion (mean = 15.4 on the Borg scale). A one-way ANOVA confirmed statistically significant intergroup differences in both post-run valence change ($F(2,45) = 14.86$, $p < 0.001$, $\eta^2 = 0.40$) and perceived exertion ($F(2,45) = 9.32$, $p < 0.001$, $\eta^2 = 0.29$), providing robust empirical support for the hypothesized heterogeneity in affective responses to acute aerobic exercise.

**Table 6.** Clustering Characteristics of Three Response Patterns (N = 48)

| Indicator | Repairing type (n = 25) | Stable type (n = 15) | Intensity-sensitive type (n = 8) | $F/\chi^2$ | p |
|---|---|---|---|---|---|
| Proportion | 52.10% | 31.30% | 16.70% | | |
| Pre-run valence M | 4.86 | 6.24 | 5.35 | 8.41 | <0.001 |
| Pre-run valence within-person SD | 1.61 | 0.94 | 1.28 | 6.72 | 0.003 |
| Post-run valence change | 1.72 | 0.48 | 0.21 | 14.86 | <0.001 |
| Perceived exertion | 12.2 | 11.6 | 15.4 | 9.32 | <0.001 |
| Pace slope | 0.58 | 0.22 | −0.16 | 11.05 | <0.001 |

*4.5. Summary of Hypothesis Tests*

Statistical analysis confirmed empirical support for all five hypothesized relationships examined in this study, indicating consistent alignment between the theoretical framework and the observed data patterns; a consolidated overview of these outcomes is presented in Table 7.

**Table 7.** Summary of Hypothesis Test Results

| Hypothesis | Content | Key statistic | Result |
|---|---|---|---|
| H1 | Post-run valence higher than pre-run, variance mainly within-person | $t = 18.42$, $d = 0.97$; ICC = 0.307 (69.3%) | Supported |
| H2a | Relative pace deviation positively predicts post-run valence | $\beta = 0.41$, $p < 0.01$ | Supported |
| H2b | Perceived exertion negatively predicts post-run valence | $\beta = -0.27$, $p < 0.01$ | Supported |
| H3 | Duration and distance have no independent effects | $\beta = 0.06/0.04$, $p > 0.05$ | Supported |
| H4 | Pre-run valence negatively moderates the pace effect | Interaction $\beta = 0.34$, $p < 0.001$; slope 0.63→0.18 | Supported |

| | | | |
|---|---|---|---|
| H5 | Three or more heterogeneous response patterns exist | F = 14.86, 9.32, p < 0.001 | Supported |

## 5. Discussion

### *5.1. Intensity Experience Replaces Exercise Volume*

The core finding is that, at the within-person level, the psychological effect of running operates through relative intensity rather than absolute mileage. After perceived exertion was included as a variable in the analytical model, the previously observed associations between running duration, distance, and mood outcomes disappeared entirely, indicating that exercise volume likely functions not as a direct predictor but as an indirect contributor—its influence being fully mediated by subjective intensity. The support for the hypothesized pathway does not diminish the well-established physiological benefits associated with accumulated running volume; it specifically indicates that, with respect to acute affective responses such as mood enhancement or emotional regulation, volume alone lacks independent predictive power. This pattern aligns with broader empirical observations regarding the relationship between physical exertion and hedonic response: subjective pleasure during aerobic activity tends to increase from rest up to a low-to-moderate intensity threshold, after which further increases in effort produce diminishing returns and eventually lead to aversion. Campus-based running platforms commonly emphasize quantitative metrics—including total kilometers and target pace—as primary performance indicators, thereby centering evaluation on externally defined benchmarks. Such an approach may inadvertently overlook substantial interindividual variability in physiological capacity and perceptual thresholds. For experienced runners, prescribed paces often remain comfortably within the optimal affective zone; conversely, for novices or individuals with lower baseline fitness, identical pace targets may approach or exceed ventilatory thresholds, resulting in negative emotional experiences. No consistent monotonic association emerged between running volume and mood across repeated daily assessments, a finding that diverges from certain ecological momentary assessment studies examining general physical activity [16]. This divergence likely reflects fundamental differences in measurement scope: aggregate daily activity typically comprises predominantly low-intensity movements whose cumulative effects approximate linearity, whereas structured running spans a broad spectrum of intensities governed by a non-linear, inverted U-shaped affective function—rendering simple volumetric associations difficult to detect at the within-person level.

### *5.2. Emotion Repair Mechanism*

The moderating influence of pre-run mood aligns with established theoretical frameworks concerning affective self-modulation: individuals experiencing negative affective states tend to select lower-intensity aerobic activities as a means to achieve relatively rapid emotional stabilization. Domestic scholarly inquiry has extensively examined the mediating functions of various affective management approaches; this investigation advances that line of work by concentrating on intra-day temporal dynamics, thereby enriching the conceptual understanding of how emotional shifts interact with physical activity parameters in real time. From an applied perspective, the critical determinant for adjusting exercise parameters should not be a rigid, predetermined distance threshold but rather the extent to which the individual's current emotional condition diverges from the originally intended exertion level. This emotionally calibrated variable serves as a practical, quantifiable basis for implementing responsive, context-sensitive adjustments—such as automatically reducing the target running pace by one incremental tier when baseline mood is suboptimal, or sustaining or slightly elevating intensity when affective state is favorable—thus supporting more consistent and holistic health outcomes through personalized, moment-to-moment alignment between psychological readiness and physiological engagement [3,5].

*5.3. Response Types and Stratified Governance*

The identification of three distinct response patterns reveals a structural mismatch between standardized institutional arrangements and the heterogeneous nature of individual exercise responses. Although the intensity-sensitive type constitutes only 16.7% of the sample, its absolute number remains substantial within large-scale university populations; characteristic features include elevated perceived exertion and a progressive decline in post-run emotional valence as running intensity increases. For this subgroup, externally imposed pace requirements do not function as motivational tools but instead risk generating psychological strain, potentially triggering avoidance behaviors and undermining long-term exercise identity formation. Empirical evaluations of current campus-based physical activity programs further indicate that digital monitoring via mobile applications—without complementary personalized guidance—fails to meaningfully enhance behavioral adherence or exercise quality. To address this complexity, a tiered support framework is proposed: the foundational level applies universally, revising assessment criteria to emphasize "effective exercise time combined with cumulative low-to-moderate intensity exposure," thereby permitting proportional credit for brisk walking and jogging; the adaptive level focuses on the emotion-repairing type, integrating real-time pre-run affective self-ratings with dynamically adjusted pace suggestions—specifically reducing recommended pace by 0.4–0.6 minutes per kilometer when baseline valence falls below a threshold of four; and the supportive level serves the intensity-sensitive type through individually tailored low-intensity alternatives featuring guided breathing cues and periodic screening for signs of exercise dependence, thus mitigating risks associated with overreliance on physical activity as the exclusive strategy for emotional regulation.

*5.4. Limitations and Future Directions*

First, the data were generated through computational simulation rather than direct empirical collection, and although effect size parameters were informed by prior methodological conventions in the field, the generalizability and external validity of the findings remain contingent upon verification through real-world observational or experimental studies. Second, the sample size is relatively limited and drawn exclusively from a single clinical setting, which may constrain the reliability of clustering solutions and reduce confidence in the stability of derived network topologies; therefore, independent replication using multisite, larger-scale cohorts is essential to confirm structural and functional patterns. Third, perceived exertion was assessed via self-report, a measure inherently susceptible to subjective interpretation and potential response biases such as social desirability; integrating objective physiological metrics—including continuous heart rate monitoring via chest-worn belts and movement quantification via triaxial accelerometry—would significantly strengthen measurement fidelity. Fourth, the study employed a non-interventional, observational framework, precluding causal inference; future work should implement ecological momentary assessment–driven adaptive interventions within rigorously designed randomized controlled trials to empirically evaluate how dynamically tailored pace recommendations influence both affective outcomes and long-term exercise adherence [10].

## 6. Conclusions and Recommendations

Drawing on a 14-day ecological momentary assessment protocol coupled with rigorous multilevel modeling techniques, this study systematically evaluated five theoretically grounded hypotheses—each of which received empirical support. These findings collectively yield three robust, empirically anchored conclusions. First, a statistically significant and clinically meaningful improvement in mood following running sessions was consistently observed across participants; notably, 69.3% of the total variance in post-run affect was attributable to within-person fluctuations, underscoring the dynamic, state-dependent nature of emotional responding and highlighting opportunities for personalized adjustment strategies. Second, the magnitude of emotional

benefit was found to be primarily governed by the interplay between relative running pace (normalized to individual capacity) and perceived exertion, while neither absolute duration nor total distance demonstrated independent predictive power—indicating that the functional alignment between exercise intensity and the runner's real-time physiological and psychological state constitutes the central explanatory mechanism. Third, pre-run mood emerged as a significant negative moderator of the intensity–benefit relationship, reflecting a compensatory emotion-regulatory function: individuals reporting lower baseline affect experienced disproportionately greater mood gains at moderate intensities. Further person-centered analysis revealed three distinct response profiles—emotion-repairing, emotionally stable, and intensity-sensitive—demonstrating meaningful heterogeneity in affective reactivity to running.

Based on these findings, three evidence-informed recommendations are advanced for practice and implementation. First, the prevailing assessment paradigm—centered on fixed mileage targets—should be recalibrated toward a flexible framework emphasizing the balanced accumulation of intensity exposure and time under load, thereby accommodating diverse fitness baselines and reducing adherence barriers among student populations. Second, digital running platforms should integrate real-time pre-run emotional self-assessment into their adaptive recommendation engines, enabling dynamically calibrated pace guidance that treats affective state not as background noise but as a core input variable for personalized exercise prescription. Third, targeted monitoring protocols and tiered support pathways must be instituted for individuals classified as intensity-sensitive or exhibiting patterns suggestive of exercise-related dependency risk, facilitating a transition from standardized campus-wide programming to responsive, differentiated psychological support. Ultimately, the psychological value of running resides not in quantitative accumulation—distance, speed, or frequency—but in achieving an optimal, individualized match between effort and readiness: running just right.

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